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ABSTRACT

In order to understand learners and players in relation to environments typically found in sport, it is necessary to first understand the individual as an information processor who must sample information from the environment, interpret it, organize or select an appropriate motor response, and execute that response. One of the most difficult processing tasks in sport is motion prediction. To examine motion prediction it is necessary to consider factors about the individual, the environment, and characteristics of the object which affect the successful completion of the goal. The factors about the individual which necessitate prediction are processing, delays, movement organization, reaction time, and movement time. It is also necessary to consider other variables such as depth perception, just noticeable difference, age, and experience. Aspects of the environment which affect performance are the number of potentially relevant stimuli in the environment, the placement of stimuli in the environment, the size of the display, the complexity of the background, the signal-to-noise ratio, and the degree of prominance of the regulatory stimuli. It is also possible to make some tentative statements on the effect of object characteristics on performance. Variables which may be considered are speed, direction, angle, viewing time, prediction distance, and object flight characteristics. Knowledge of the characteristics and effects of these three factors should aid teachers in facilitating learning and performance in skills. (BD)

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AN INFORMATION PROCESSING APPROACH TO SKILL ACQUISITION: PERCEPTION AND TIMING[1]

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An Information Processing Approach to Skill Acquisition:

Perception and Timing

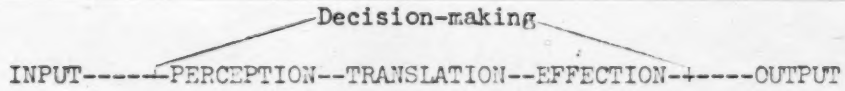
Introduction

In order to understand learners and players in relation to environments typically found in sport, we must first understand the individual as an INFORMATION PROCESSOR. The simplest model of information processing we can conceive of is the one proposed by Whiting (1969):

INPUT----------DECISION-MAKING----------OUTPUT

The individual receives information from the environment, processes it, and comes to some decision, then executes a response, which we may observe.

The complexity of the model may be increased somewhat if the decision-making segment is expanded in the following way:



In this extension of the model the individual acquires information from the environment, interprets it, transforms it, plans a motor response, and emits that response. Welford (1968) has suggested that perception involves the integration and identification of sensory input; translation involves choice of response in relation to what is perceived, perceptual-motor match; and effection involves the coordination and phasing of the movement.

In a further extension of the model, it is possible to add the dimensions of: short term store, selective filter, long term store, choice delay, rehearsal loop, and information feedback, and consider the model culled from Broadbent, Welford, Craik and others by Stallings (1973) and presented as Figure 1.

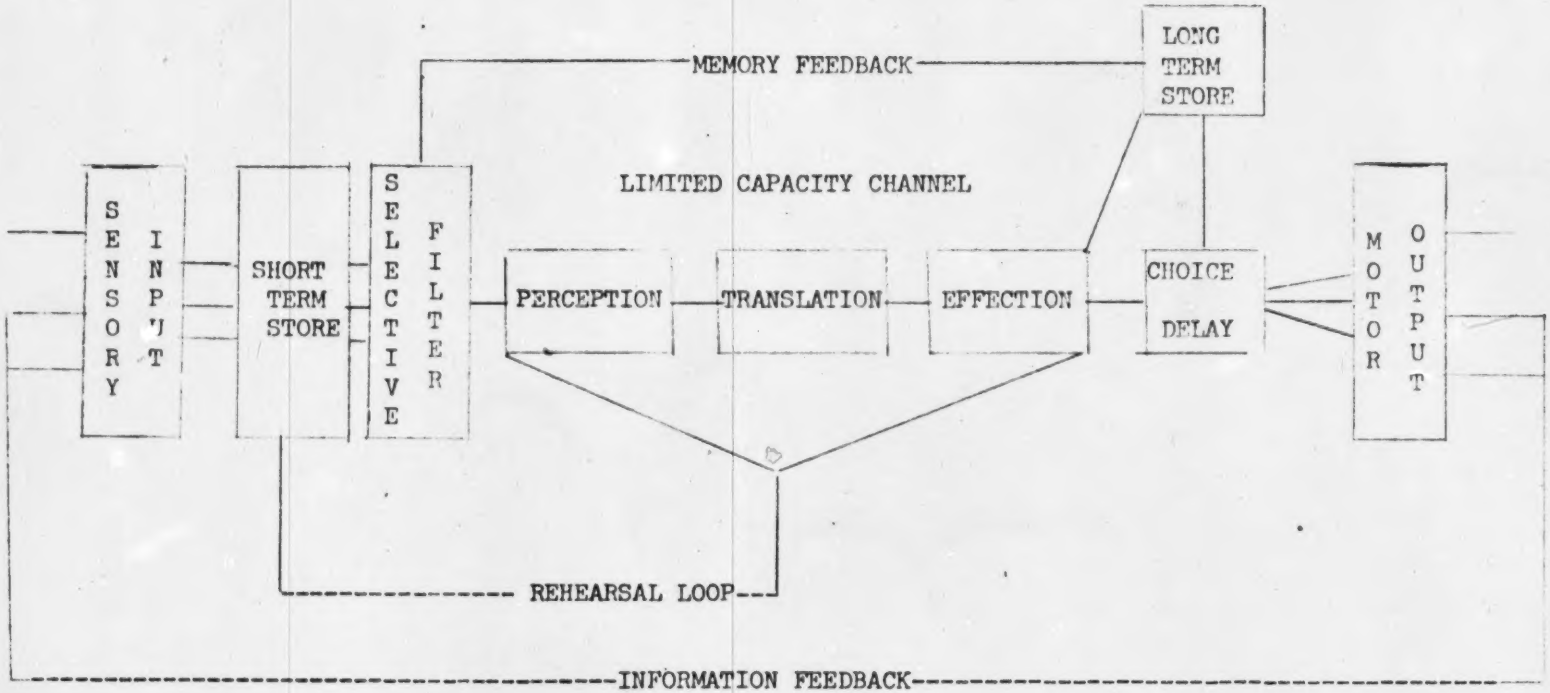


FIGURE 1: INFORMATION PROCESSING MODEL (Stallings, 1973, p. 51)

Information received from the environment is held in short term storage and selectively filtered, the concepts of Gentile regarding regulatory and non-regulatory stimuli are useful here. Information that is filtered, or passed through, is treated in the limited capacity channel, as previously explained with reference to the expanded version of the Whiting model, but in this instance the plan can be formulated and then delayed for a chosen length of time, i.e. selective emission of motor plans in order to match optimal environmental conditions. Information feedback, long term store, memory feedback, and rehearsal loop all play a role in increased efficiency of the system. Through information feedback, plans can be modified to meet changing environmental configurations or failures in process; through long term store information is available for use at other times, so plans which have proven effective can be used again; the memory feedback system enables the learner to choose "correct" or regulatory stimuli and ignore the "noise" and the rehearsal loop may serve to increase the duration of temporary storage.

One of the most difficult information processing tasks in sport, and the one which will be focussed upon today, is that of motion prediction. The type of task which will be considered is one which takes place in an open environment. According to Higgins and Spaeth (1972) the catagorization of environments as open and closed must be based on two factors: the trial to trial variation, and the intra-trial variation in spatial and temporal aspects. The motion prediction tasks which occur in sport generally have much variability from trial to trial and since th objects are in motion have within trial variability. In addition, the object may move at a constant rate of speed or may have variable motion, acceleration or decleration. This consideration of inter and intra-trial variability has been diagrammed and is presented in Figure 2.

INTER-TRIAL VARIATION

INTRA-TRIAL VARIATION	ABSENT	PRESENT
ABSENT	CLASSIC CLOSED	
PRESENT CONSTANT		
PRESENT VARIABLE		CLASSIC OPEN

FIGURE 2. A Consideration of the space-time variables in the skill environment

Higgins, 1974

The supposition with the model is that the skill becomes more difficult as the skill moves from left to right and from top to bottom. Another way of illustrating this has been attempted by Rothstein (1975) and essentially separates the space and time factors. The classification system becomes highly complex and some of the combinations are somewhat difficult to find examples for, but most can be produced experimentally. It seems more realistic in assessing the effect of spatial and temporal variation to consider them as independent factors. Since the separation of the space-time factors is essentially an academic exercise and not essential to the ensuing discussion, it won't be pursued here.

In a true open environment, everything varies, including such things as number of stimuli, both regulatory and non-regulatory, number of response choices, and noise-to-signal ratio, and the player must rely on the ability to extract the relevant cues and predict. Wiener (1962) defines motion prediction as "an extrapolation to a future position (of an object) from current information." In a true open skill the goal of the participant is to match the movement to the particular characteristics of the environment at the instant of response completion. The three crucial aspects of the last sentence with regard to the ensuing discussion are: match, particular characteristics, and response completion.

The performer receives, via appropriate sensory channels, various stimuli from the environment, these stimuli may be relevant (regulatory) or irrelevant (non-regulatory) to the skill execution, the performer must select the particular characteristics which are regulatory and ignore others. On the basis of stimuli attended to the performer must select from an existing repetoire, or must plan, a response which will match the environment as it will be at the completion of the response. After selecting the response which is most appropriate the learner must then

decide when to initiate that response. All this must be accomplished in .2 seconds.

For the remainder of this presentation we will be concerned with the learner or participant as an information processor who must sample information from the environment, interpret it, organize or select an appropriate motor response, and execute that response so that its completion coincides with the predicted arrival of the object. In order to accomplish this most effectively we will consider factors about the individual, factors about the environment, and finally characteristics of the object which effect the successful completion of the goal. The factors to be considered under each of these catagories are listed in Table 1. In addition, for your information, some of the commonly used measures are also indicated in Table 1.

THE INDIVIDUAL

Why is it necessary for the individual to predict? What factors about the individual effect the ability to predict? What does the individual have to do in order to effectively intercept or strike an object:

It has been intimated that time is consumed by selection of information from the environment. Once this information is selected the individual must plan or select an appropriate movement; this process of decision-making takes considerable time. In addition, there is "system lag", the time from the initiation of the response until its completion, which is generally equal to one reaction time (RT) plus one movement time (MT).

In the preceding, four factors about the individual which necessitate prediction have been identified. They are: processing delays, movement organization; reaction time; and movement time. Let us consider each of these briefly and see how they effect the task confronting our learner.

TABLE 1: VARIABLES EFFECTING PREDICTION

THE INDIVIDUAL

PROCESSING DELAYS
TIME FOR MOVEMENT ORGANIZATION
MOVEMENT TIME
REACTION TIME
DEPTH PERCEPTION
j.n.d.
AGE
EXPERIENCE
PERSONALITY
VISUAL FACTORS
STRATEGIES

THE ENVIRONMENT

NUMBER OF POTENTIALLY REGULATORY STIMULI
POSITION OF STIMULI IN THE ENVIRONMENT
SIZE OF DISPLAY
NOVELTY OF DISPLAY
COMPLEXITY OF BACKGROUND
SIGNAL-TO-NOISE RATIO
PROMINANCE OF REGULATORY STIMULI

THE OBJECT

SPEED
DIRECTION
ANGLE
VIEWING TIME
PREDICTION DISTANCE
OBJECT FLIGHT CHARACTERISTICS

COMMON MEASURES

VISUAL SPEED
PERCEPTUAL SPEED
TEMPORAL ERROR
DISTANCE ERROR
ACCURACY
TASK ACCOMPLISHMENT
EYE FIXATIONS
- DURATION
- NUMBER
- PATTERN

MOVEMENT ORGANIZATION
- SPATIAL
- TEMPORAL

Processing delays. Processing delays may be caused by two sub-factors: time lags in the nervous system, the time for information, received via the sense organs, to reach the central nervous system; and time to pick up the information from the display. There is little,if anything, that the individual can do to change the inherent transmission time, but the time for pick up of information seems to be related to familiarity and experience in the environment. This latter has been recently demonstrated by Bard (1974) who looked at the number of eye fixations and the duration and pattern of eye fixations in a stationery environment. Slides of various basketball situations were presented and the individual was required to indicate whether the most appropriate response, for the ball carrier, would be to pass, dribble, or shoot. Her findings, some of which are presented as Figures 3, 4, and 5, led to the conclusion that the unskilled players, who it was inferred, had not learned how to look or what to look at, evidenced more eye movements, longer fixations, and patterns which were more random that those of skilled players. It was noted, however, that the unskilled players did improve with practice. One typical pattern of a skilled and unskilled player on the third presentation of the same slides illustrates the differences which still existed after practice. It is probable that. refering back to Figure 1 on page 2, the skilled player uses information from the long term store to guide their selective attention.

A somewhat related phenomenon is cue abbreviation. Skilled players are able to shorten their processing time by predicting from early environmental cues rather than waiting for further information from the environment. It is possible that highly skilled performers have gnostic units, such as those postulated by Knorski (1967), which enable them to quickly predict the arrival of objects and subsequent information only serves as confirmatory

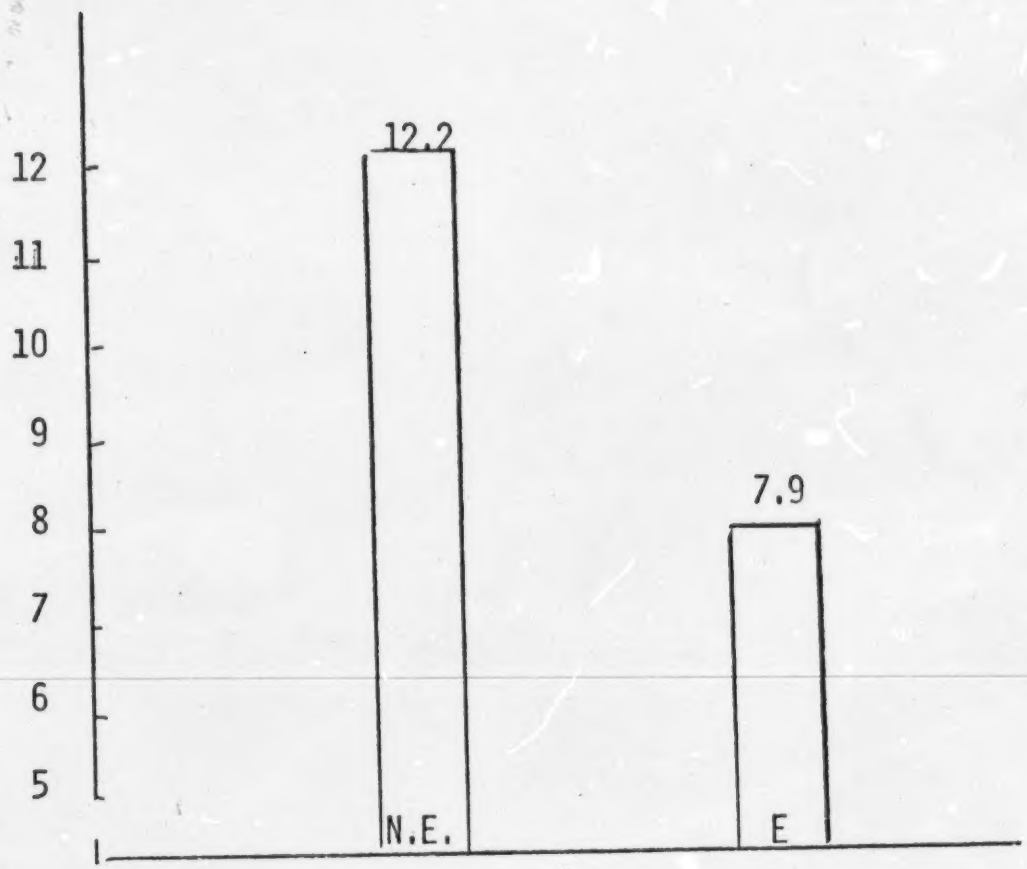


FIGURE 3: AVERAGE NUMBER OF EYE FIXATIONS (BARD, 1974)

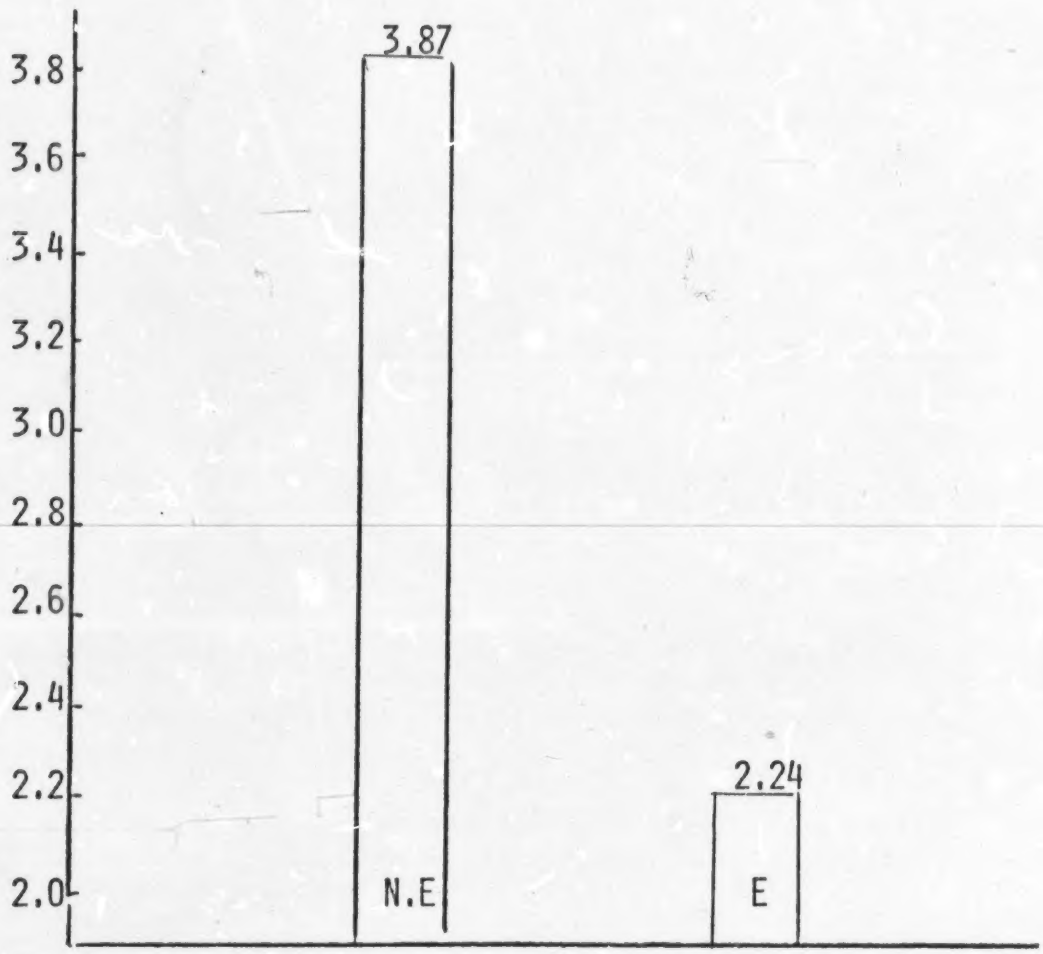
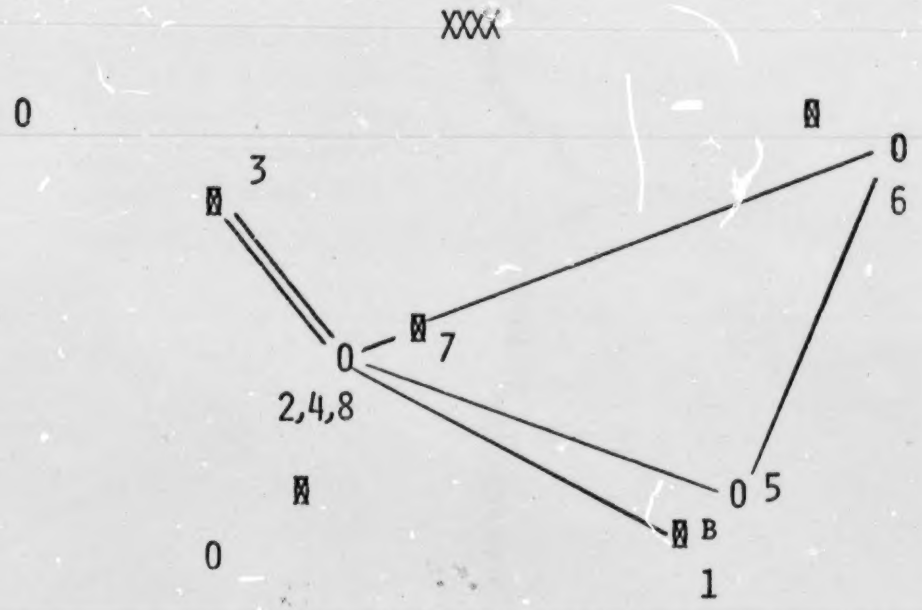
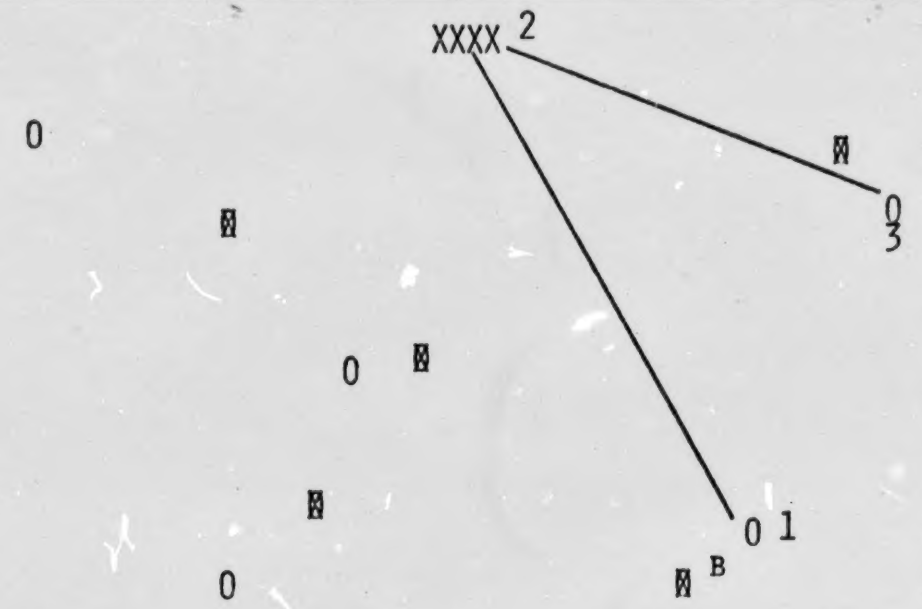


FIGURE 4: AVERAGE TIME OF FIXATION
(BARD, 1974)

FIGURE 5: EYE MOVEMENT PATTERNS OF SKILLED AND UNSKILLED Ss. (BARD, 1974)



NON-EXPERIMENTAL PRESENTATION #3
SUBJECT 3
DIAGRAM 2



EXPERIMENTAL PRESENTATION #3
SUBJECT 15
DIAGRAM 2

evidence.

There is information (Whiting, 1969; Bassin, 1975) that individuals may vary in the amount of information necessary for predictions, apart from their skill level. It has been suggested that awareness of the style of processing information may be helpful to the teacher in enabling him/her to use appropriate teaching cues for learners of various types. For a late sampler, attention might be directed to the availability of early cues which may be interpreted; while for an early sampler, the teacher may wish to suggest strategies for delaying response initiation.

There seems to be some difficulty in attempting to measure processing time of different subjects, but Davis (1972) has suggested that in considering the perceptual aspect of the coincidence-anticipation task, we look at the movement response time (MRT). This is defined as the time left, after processing, for organizing and emiting a movement response. This is a worthwhile suggestion since it seems to be a more accurate assessment of the actual performance task confronting the learner. What we don't know is whether this measure is affected by the necessity of organizing a movement; however, it seems that it would be. This brings us to a consideration of movement organization from the standpoint of the delay inherent in the need to either select from among alternative responses or plan a new response.

Movement organization. Subsequent to the processing of information the performer must decide what to do about it. "How shall I move in relation to the stimulus configuration confronting me?" As you can imagine, highly skilled performers have a richer background of movement experience and so can organize an appropriate match more quickly or choose one which matches from an existing repetoire. The ability to select and/or organize an appropriate response may be related to the concept of motor schema first suggested by Broadbent and Welford but recently revived by Schmidt (1974).

According to this theory, the more experience an individual has the more sets of perceptual-motor matches are available and the more quickly new sets can be interpolated. There is also some indication that more experienced players utilize strategies of response selection which are more rapid than those employed by inexperienced players.

Reaction time. The delay which is due to reaction time is similar to the processing lag due to transmission of information into the systém, except that in this case the information is being transmitted out. It is the time between a command and its initiation. Normally reaction time is tested by having the S release a key with the onset of a light. The lag due to reaction time does not change, except with age (and possibly due to fatigue, or chemical changes in the nervous system). The performer in a reaction time situation which is appropriately structured may learn to anticipate the onset of the stimulus and initiate the response in order that its completion be coincident with the onset of the stimulus.

Due to the decrease in reaction time with age it is clear that younger children must initiate their movement responses earlier than older children. In the case of a task with involves coincidence-anticipation it is clear that younger children would have to predict and initiate their responses far earlier than older children. This notion was supported by Stadulis (1971) and Schwartz (1974) when one of the object speeds, due to a backspin on the ball, failed to accelerate at the expected rate but instead declerated. The observed error led to the conclusion that in the case of the younger children, the response had been initiated prior to the point in the track at which the slowing occurred. The ability to control the occurrence of this event experimentally would give us tremendous insight into the processing of information by different age groups, at different speeds, at various angles, which has been difficult to obtain effectively.

Movement time. Unlike reaction time, movement time is modifiable. The speed of movement may be increased by increase in muscle strength, recruitment of more motor units, and the shortening of lever length, to among other possibilities. Skilled players tend to have consistent movement time and seem to rely on judicious use of delay to coincide the completion of their total movement with the object. (Felman, 1966; Hubbard and Seng, 1954; Spaeth, 1973) Regardless of how the execution of the movement is accomplished and the exact timing of it, the performer must accurately assess the arrival of the object and initiate the response one RT and one MT prior to the arrival (or estimated arrival) of the object in order to be coincident with it.

In order to account for a majority of the variables effecting the individual's ability to perform tasks requiring coincidence-anticipation we should briefly consider these other variables: depth perception, j.n.d., age, and experience.

Depth perception. Depth perception is the ability of the individual to determine the distance between two objects which are varying distances from him/her. While it is likely that the individual could learn to interpret ambiguous cues for depth with practice, much in the same way peripheral vision can be improved with practice, there is probably a threshold for each individual which is determined by various system parameters. (Retinal disparity, which is a binocular cue and therefore crucial at distances greater than 20', may be an example of a system parameter which effects this threshold.) Depth perception is significant because individuals who can resolve finer cues of this nature may be able to assess ball flight changes, accleration, decleration, more rapidly and readily and thereby leave themselves more time to plan or organize and initiate the appropriate response.

j.n.d. Another factor related to the individuals perceptual ability is the just noticeable difference (j.n.d.). This refers to the amount of change of one stimulus, as in an object which travels toward a player, or the magnitude of difference between two stimuli, as in two objects at different distances from the player, which is necessary before an individual can report that there is a difference. In the case of a moving object this may refer to the ability to detect acceleration and decleration of the object as well as constant velocity. The j.n.d. is usually reported as a percent. For velocity this percent has been reported to vary between 25-40%. A study is underway to determine the extent of individual difference in this parameter and the extent to which it actually effects prediction.

Age. Regardless of which of the variables is chosen as the indicator of coincidence-anticipation ability, it is clear that ability to coincide a response with a moving object increases with age. An interesting finding, however, is that young children seem to have greater difficulty with slow moving objects. The information with respect to age is difficult to interpret due to the confounding effects of information processing, cognitive ability, immaturity of the visual apparatus, development of the nervous system, and the inability of experimenters to differentiate among the different components of the task. One suggested way of looking at the components of the task is presented as Table 2. (Rothstein, 1975)

Experience. A number of studies have been presented which have pointed up the differences in coincidence-anticipation, or prediction ability, between skilled and unskilled players. The problems associated with processing of information from the environment have been mentioned, but, in addition, the factors of perceptual speed, availability of schemas, and the early sampler, late sampler problem are also relevant. Relative to the question of, "What

TABLE 2: Delineation of sub-areas of coincidence-anticipation[1]

A. Sensory components
- Visual acuity
- Depth perception
- Peripheral vision
- Interpupillary distance
- Eye-hand dominance
- *Others to be added

B. Perceptual components
- Spatial discrimination: differentiate object directions
- Temporal discrimination: differentiate time units
- Spatial-temporal discrimination: differentiate combinations of events

C. Central components
- Spatial prediction: anticipate where object will arrive
- Temporal prediction: anticipate when an object will arrive
- Spatial-temporal prediction: anticipate when and where an object will arrive

D. Motor components
- Spatial control: regulation of output with regard to direction and/or distance
- Temporal control: regulation of output with regard to time of initiation and/or intra-movement variables
- Spatial-temporal control: regulation of both aspects simultaneously

E. Perceptual-motor components
- Spatial integration: interaction of the three spatial processes
- Temporal integration: interaction of the three temporal processes
- Spatial-temporal integration: interaction of the three spatial-temporal processes

F. Strategies in prediction
- Space cues
- Velocity cues
- Time cues
- Orienting strategies
- Schemas
- Cue abbreviation
- *Others to be added

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[1]This table is not intended to be a hierarchial presentation in a developmental sense since only limited information in this regard is presently available.

came first, the ability or the experience?", a recently completed study by Stankard (1975) revealed that high school students who were not involved in sport activities to a high degree formed two distinct groups when tested on a spatial prediction task. (Haskins, 1965) The better group, with more correct responses, was not significantly different from a group of varsity open skill athletes in the college sample. The poorer high school group was significantly different from both the better group and the varsity college sample. The question arises as to whether the varsity players were better able to predict because of their experience or did they become varsity players due to a superior ability to predict?

It would seem clear that in teaching individuals skills which involve coincidence-anticipation the limitations imposed by individual differences must be considered. Those reviewed here are: processing delays, movement organization, reaction time, movement time, depth perception, j.n.d., age, experience, and possibly perceptual style. Let us turn now to another catagory of factors and consider aspects of the environment which effect performance.

THE ENVIRONMENT

There are several factors related to the total display - which may influence the perception of and consequent prediction of the object. These factors relate to: the number of potentially relevant stimuli in the environment; the placement of stimuli in the environment; the size of the display; the complexity of the background; the signal-to-noise ratio; and the degree of prominance of the regulatory stimuli. The latter three factors can be grouped under the broader heading, figure-ground.

Number of potentially regulatory stimuli. A potentially regulatory stimulus is one which may have relevance for goal attainment through constraints upon the motor plan. As the number of potentially regulatory stimuli increase the time required for processing and perception will increase. For most softball players, as an example, the preliminary motions of the pitcher have some relevance or potential relevance for the initiation and/or spatial configuration of the swing. An unskilled or inexperienced player may not be able to discriminate as effectively as a more skilled player and so may attempt to "attend to" many more of the stimuli than is necessary. In the Bard study, referred to earlier, there was a marked difference in the number of stimuli "looked at" by the unskilled as contrasted to the skilled players. For the unskilled player all of the stimuli "looked at" were potentially regulatory, for her and much time was wasted processing the irrelevant information. The skilled players were quickly able to eliminate many of the stimuli thereby reducing the time spent. It is clear that this ability is largely a function of experience and seems to be situation specific although it may be that skilled players have different looking strategies which may be useful in other situations as well.

The placement of stimuli in the environment. The placement of stimuli in the environment and the total size of the display are somewhat related in that the latter will be affected by the former. If the placement of the stimuli are such that the player must make both eye and head movements in bringing them into focus the time to process the information will be greater than if only the eyes move, and that will take more time than if the entire display is visible without moving the eyes or head at all. If in addition to the size, the environment is also unfamiliar then players will make many more orienting responses to inappropriate stimuli. This

tendancy may be greater on the part of a player who is less skilled.

Figure-ground. Included here are the factors of background complexity, signal-to-noise ratio, and the degree of prominance of the regulatory stimuli. It is clear that the degree to which an object stands out from the background will influence the Ss ability to accurately predict object characteristics. Gottsanker (1952, 1956, 1962) has completed several studies in which the background, behind a laterally moving object was varied and has concluded that the variability effects prediction. In addition the degree of complexity of the background seems to effect the ability to selectively attend or to pick the object out of the background rapidly. Oddly enough, however, the complex background appears to "force" the S to concentrate more vigorously on the object and this concentration seems to carry over to performance in a simple background. Upon transfer to a simple background Ss who learned or practiced in a complex background situation in their performance markedly, even to a greater extent than a group which began on the simple background. As might be expected, performance for the group switching from the simple to the complex background deteriorates rapidly.

Increasing the signal-to-noise ratio increases the difficulty of picking out the regulatory cues. Williams (1973) suggested that children tend to have high signal-to-noise ratios. Is it possible that the same may be true of unskilled players? This again will have the effect of increasing the processing time. The signal-to-noise ratio can be reduced by removing all or part of the noise from the environment. Those stimuli which represent noise, however, should gradually be added as the regulatory stimuli acquire value for the player. A related concern is the prominance of the regulatory stimuli. In sport a player must localize, detect, resolve and recognize the ball and predict the arrival time before choosing a movement pattern which matches. The prominance of the regulatory stimuli

will effectively decrease the time necessary to accomplish this. In a study which investigated the enhancement of regulatory stimuli with day-glo paint, coupled with the use of black light drills,(Antonaccio, 1972) it appeared that the experimental group of intermediate fencers were better able to successfully avoid touches, by parrying and other defensive measures, than a group of intermediate fencers who did the same drills with the same experimenter under normal light without day-glo. The stimuli enhanced were the foil tip and the target and the fencers drilled, under the assigned condition for 1/4 of the total class time per week. When the study was replicated a second time, with beginning fencers, no significant differences were noted. It is possible, however, that the beginners had to devote so much attention to the actual motor output that they were unable to devote attention to the environment to the extent necessary. Similar findings were noted by Haskins, cited previously, in reporting on the use of a spatial prediction film for tennis. She concluded that although the spatial prediction ability of the beginners improved, they could now get there faster and sooner, the lack of a concommitant increase in the motor control aspect prevented improvement in the overall ability.

One major difficulty with should be mentioned relative to the use of these techniques, is that different players may use different cues from the environment and beginners may use different cues than do intermediates or experts. Therefore we need to be sure that those stimuli which we are enhancing are indeed the ones which are most appropriate for the level of student we are working with.

Generally we may conclude that some background against which the object may be judged is necessary, but the the degree of complexity, the noise-to-signal ratio, the size of the display, the novelty of the display, and the

prominance of the regulatory stimuli are crucial to the detection, localization, recognition, and resolution of the object, all of which are pre-requisite to accurate prediction.

THE OBJECT

Due to the unsystematic nature of the total research effort in the area of coincidence-anticipation, it would seem impossible to make any general statements about the effects of object characteristics on performance. Couple this with some of the difficulties of what actually constitutes an appropriate independent variable and the generalization process becomes even more difficult. In spite of these problems and others to be mentioned it is possible to make some tentative statements about the variables. Those to be considered are: speed, direction, angle, viewing time, prediction distance and object flight characteristics.

Let us turn briefly to some problems effecting the interpretation of the effect of the variables to be considered. It seems useful to consider the notion of the hitting zone as perhaps a more reasonable concept than intercept point. An object passes through the intercept point but cannot really be said to be "in" the intercept point. It is more realistic, in terms of the idea to be developed, to speak in terms of a "hitting zone" and to relate speed and error measures to the time the ball is in the hitting zone and available for the player. In addition we may consider the various strategies a player may use to change the size of the hitting zone and so reduce the likelihood for error. For example, a player who is executing a one hand catch of a fast ball may "give" with the ball to a greater extent than he would on a slow moving object. He has, in effect , changed the catching zone. He can, in this way, compensate for errors which may be made in the prediction of the

arrival of the object or in the response execution.

If we accept the concept of the hitting zone than it makes sense to look at error in terms of "where" in the hitting zone the player contacted the ball. This may be true in the case of the intercept point also, but there are other pluses to the hitting zone concept. Distance error would not be effected by the speed of the object in the same way the time error would. Consider for example the information presented in Table 3. The length of the hitting zone has been arbitrarily set at one foot for ease of calculation and it is assumed that the S makes a 50% error in each case. If absolute temporal error is used then it appears that the slow ball speed causes the S to make larger errors, when in fact, if we look at distance error, we find that the S was actually equally close to the intercept point, the exact center of the hitting zone, in all cases. In most studies the Ss don't make 50% errors at all of the speeds, but they do appear to be less accurate at the slower speeds when temporal error is used as our measure of accuracy. Distance error, then, appears to give a more accurate picture of the subject's performance. In addition, with temporal error any comparision between or among speeds will give fallacious results and so if temporal error is used the comparison should be limited to within speed or within track analysis.

In order to see what differences this conversion would make the data from two studies has been converted. In the Pavlis study (1972) data, which is presented as Table 4, we see that the 7 year olds were still poor, with the distance error conversion, at the slow speed, but, for the 9 and 11 year olds the change in dependent variable would lead us to conclude that as object speed increased, accuracy decreased.

For data gathered by Alderson (1972) the differences in directional error for speed over stimulus distance and in variable error for speed over

OBJECT SPEED (fps)	2.5	5	10	20	40
TIME IN HITTING ZONE (sec)	.4	.2	.1	.05	.025
TEMPORAL ERROR(sec)	.2	.1	.05	.025	.0125
DISTANCE ERROR (in.)	6	6	6	6	6

TABLE 3: A COMPARISON OF TEMPORAL AND DISTANCE ERROR SCORES IN A COINCIDENCE TASK

Table 4. Mean distance error for age, sex, and feedback.
(data converted from Pavlis, 1972)

Track		1		2		3	
Speed (fps)		7.20		3.47		2.11	
AGE	7	.088s	.63 feet	.091s	.32 feet	1.089s	2.30 feet
	9	.078	.56	.065	.23	.070	.15
	11	.059	.42	.057	.20	.066	.14
SEX	MALE	.084	.60	.068	.24	.089	.19
	FEMALE	.066	.48	.075	.26	.075	.16
FB	DIR.	.076	.55	.067	.23	.085	.18
	CON.	.074	.53	.075	.26	.078	.16

stimulus distance when distance error is used are apparent. These are presented as Figures 7, 8, 9, 10. It can be seen that the differences become more marked when the data are converted, although in the case of the velocity-stimulus distance comparison (mean directional error) the shape and relationships remain generally the same. (Figures 7 and 8) For the variable distance error, in contrast to the variable time error, the relationships among the three curves appear to change somewhat. (Figures 9 and 10) Interpretation of the velocity-stimulus distance data should be tempered by the observation, reported by Alderson (1972) that different personality types seem to have different directional error patterns. This tends to support a notion mentioned earlier with regard to individual differences and coincidence-anticipation behavior. The information just presented would suggest that we view interpretation of data based upon temporal error measures with caution.

Another problem associated with interpretation relates to the use of apparatuses of various lengths, from 4' to 25'. Alderson reported surprise at the finding that his results were compatible with other data gather over shorter ball distances. It may be that the time a ball is in motion is an important variable rather than the distance traveled. We can use the equation speed = distance/time and solve for time. Therefore time = speed/distance. In Alderson's approximately 24' of track a ball traveling at 10fps would travel to the intercept point in 2.4 seconds; a 20fps ball would reach the intercept point in 1.2 seconds; and a 30fps ball in .8 seconds. On a 6' apparatus the ball traveling at 3fps would reach the intercept point in 2 seconds; a 6fps object in 1 second; and an 8fps object in .75 seconds. Since we have not tested the same Ss on the different apparatuses this hypothesis has not been tested. In a study by Felman (1966) it was noted that optimum performance was obtained at the highest speed for a 4' distance,

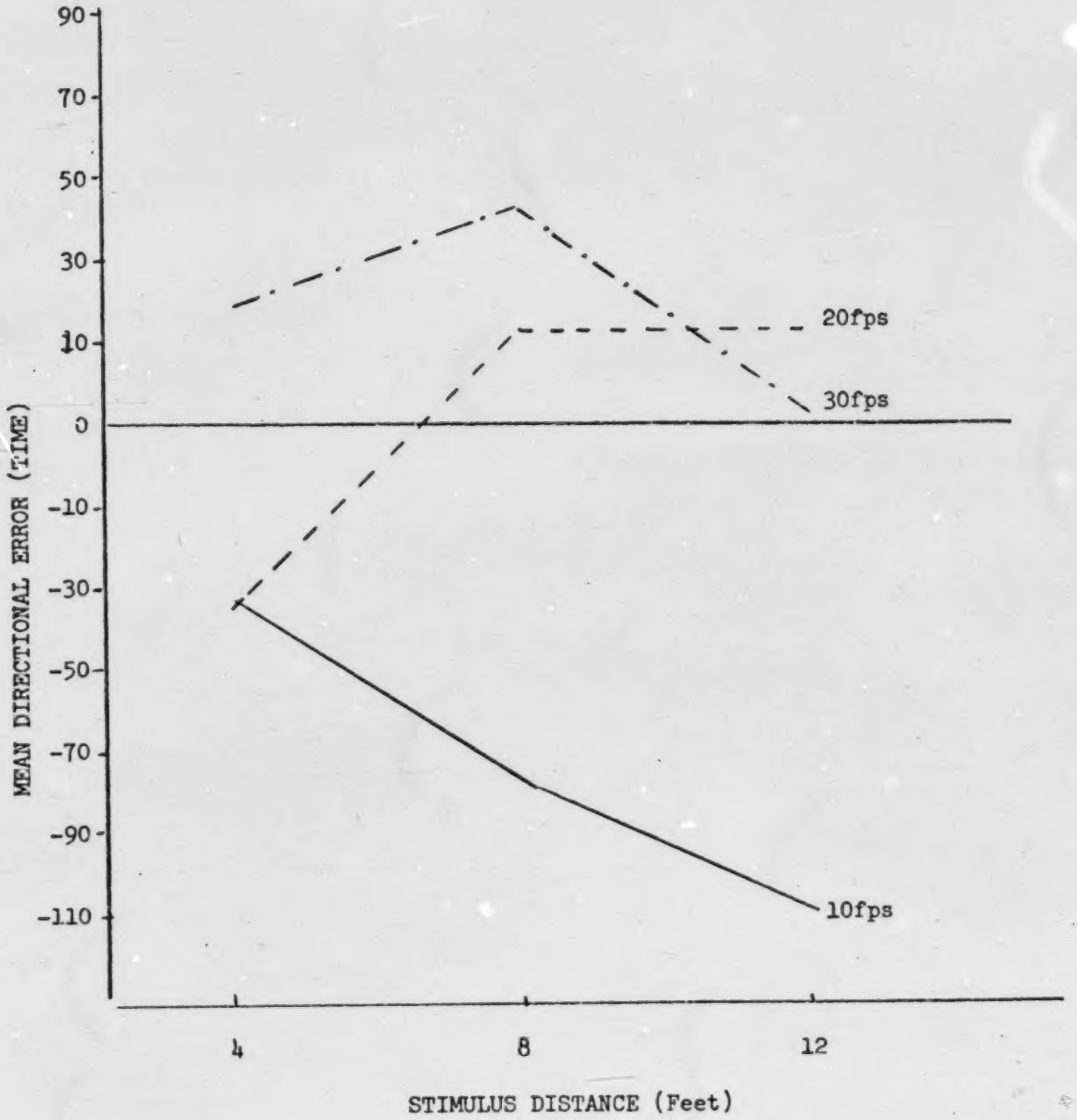


Figure 7: Mean directional error (time) for velocity and stimulus distance.

(Alderson, 1972)

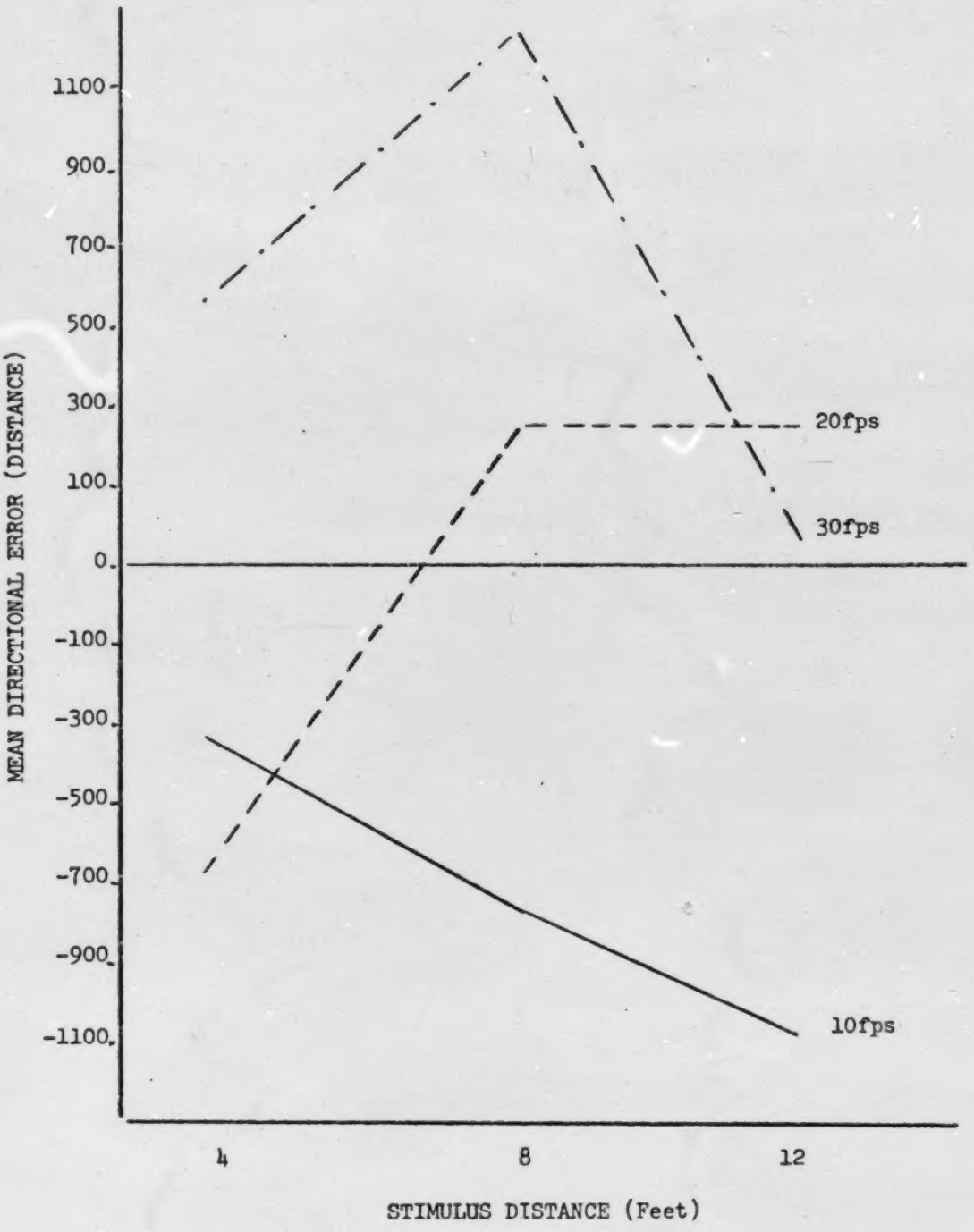


Figure 8: Mean directional error (distance) for velocity and stimulus distance.

(converted from Alderson, 1972)

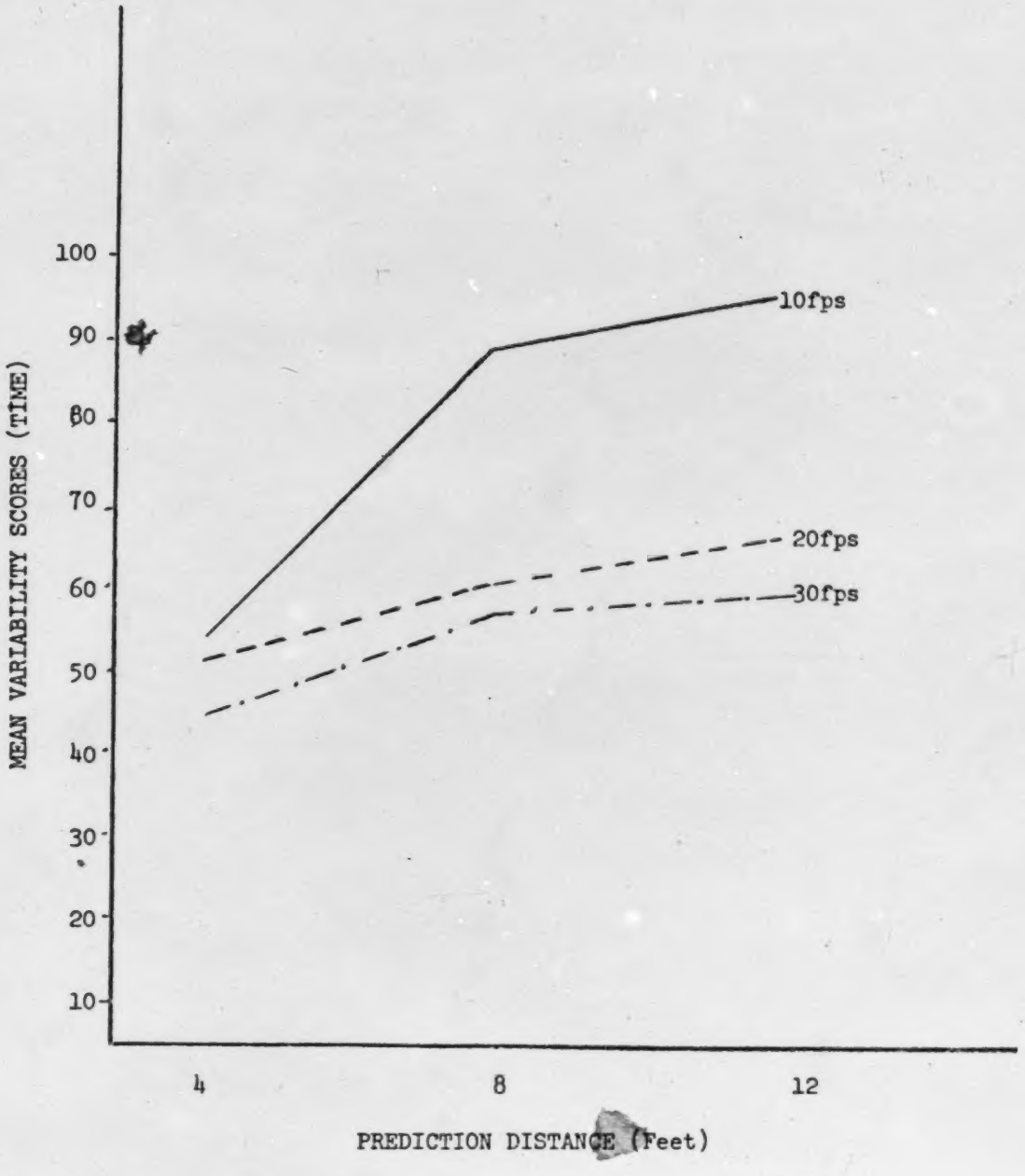


Figure 9: Mean variable error for velocity and prediction distance

Alderson, 1972

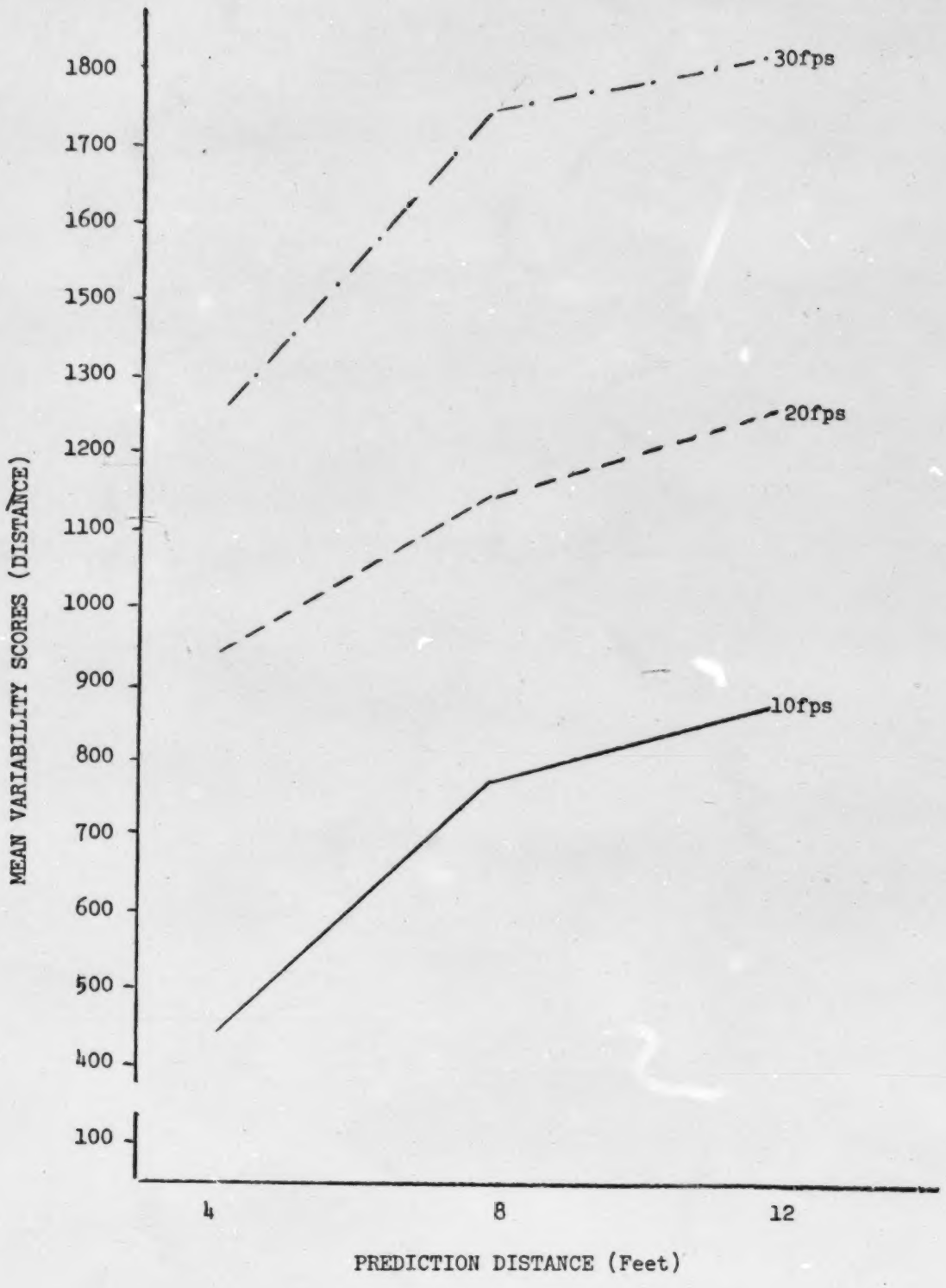


Figure 10: Mean variable distance error for velocity and prediction distance converted from Alderson, 1972

the speed of the object was 6.8fps, and for the slowest speed, 3.1fps, optimum performance was obtained at the longest distance, 9'. This may be related to the difficulty inherent in judging slow speeds, possibly due to the j.n.d. problem, or to the fact that in Felman's long track eye-head movment was necessary and in the short track it might not have been.

A final difficulty inherent in the interpretation of results is the observation of consistent three and four way interactions in many of the studies which have manipulated object variables. The efficacy of drawing generalizations about each of the variables in turn is therefore questionable. In addition, the difficulty of measuring coincidence-anticipation ability in the normal environment is apparent and has necessitated the design of many artificial means of manipulating object characteristics. Please bear this in mind and note that as a consequence the statements to be made here are tentative understatements at best and subject to many ifs.

Speed. Young children seem to have greater difficulty with slower speeds and tend to be more variable in their responses; while older children tend to be more accurate at the slower speeds and show increasing error at the faster speeds. It has sometimes been noted that unskilled players are similar to children in difficulty with slow speed objects.

Direction. Direction of the object may be towards or away from the player or may move across the players line of vision, and in this context, may move from right to left or left to right. It seems that objects moving toward the S are more accurately predicted or anticipated than objects moving away from the S though there are some studies which have failed to demonstrate a difference in this variable. It has also been noted that S can better judge an object coming toward her/him than

those which move across the line of vision. It also seems that Ss have more difficulty with object moving from right to left across the line of vision. This finding may be somewhat related to experience and will be mentioned again in another context with regard to a study by Snyder(1969). An interesting study may be to not only have the object move toward the S but to have the S move toward the object and either have the S self-initiate and control movement or have the movement externally controlled, as on a moving sled.

Angle. The angle of the object refers to the right, left, and center location of objects with regard to the S. Generally, young children appear to have difficulty with objects which are either to the right or the left, but older Ss appear to have difficulty only with objects to the left. It is unclear exactly why the observation has been generally noted but since 20% of the population is left-handed we can assume that in any random sample for an experiment at least 80% or more individuals will be right handed. It may be that dominance and ability to interpret objects traveling at various angles are related. If this were true, simply replicating some of the work with a population of left-handed Ss should give the opposite results, they should have greater difficulty with objects from the right angles. Another possibility is that the world is generally a right handed one and individuals, regardless of hand preference,must learn to interact with it. We may also invoke the idea of schemas in explaining the developmental and adult observations.

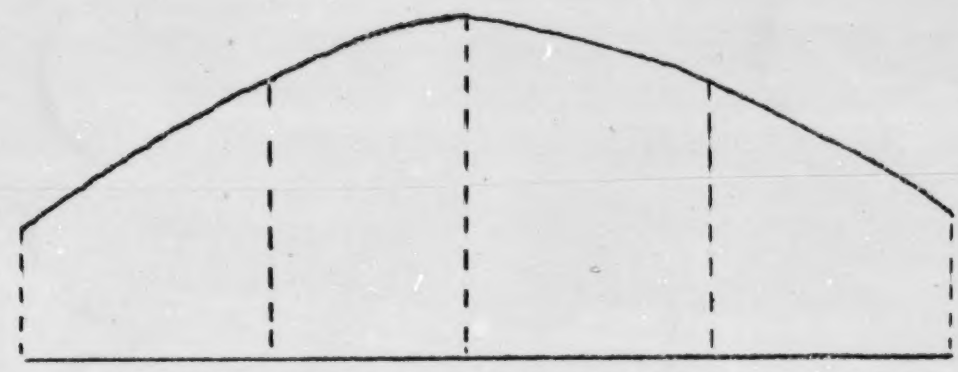
Generally, with respect to all of the above variables, it has been noted that a particular combination of speed, direction, horizontal and vertical angle will produce the best results. This would lead us to suggest that students would do best if exposed to a wide variation of combinations of these variables. In addition, it would be interesting to

survey the world of objects and determine which segments of the world of a typical subject in a particular sport are most used and determine whether that observation corresponds with our experimental observations. Further, individuals who participate in sports in which objects generally move in a particular segment of the world should be better at discriminating and predicting, and responding to, objects in that segment. For example, soccer players who have never played sports which involve use of implements held in the hands or response to objects to the midline of the body, should not do as well in predicting the arrival of objects in Haskins (1965) film as tennis players.

Viewing time and prediction distance. The bulk of research on viewing time and prediction distance has been conducted at the University of Leeds under the direction of H.T.A. Whiting. Initial studies looked at the effect of time of ball flight illumination and catching performance. The longer the S viewed the ball the greater the improvement in performance.

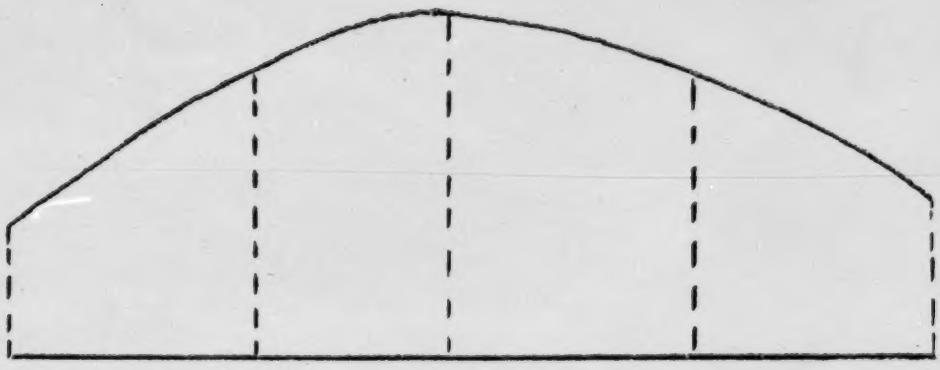
The next stage of work related to the manipulation of viewing time, or stimulus distance, prediction distance, and speed. Alderson (1972) used a constant speed array involving linear motion from right to left, and found that increased variability in response time was associated with longer prediction distance and increased speed. Stimulus distance results were confounded by effect of personality.

Whiting and others then pursued a line of investigation which led them to vary the viewing time and the occluded time in the hope that the relationship between input and movement organization could be established. The speed of the object was not varied and only "good" catchers were used as Ss. The initial paridigm is illustrated as Figure 11 and the obtained results seem to indicate that with a viewing period of 80 msec an occlusion period of 160 msec seems to be optimum. In a second study, the paridigm is presented as Figure 12, viewing time and occlusion time were varied. The observed



Whiting and Sharp, 1974

Figure 11: Paridigm for viewing time experiment.



Sharp and Whiting, 1974

Figure 12: Paridigm for viewing time experiment 2. Viewing period within S; occluded period between S.

results are presented as Figure 13. Please note that the original presentation by Whiting had the variables reversed with the between Ss variable as the horizontal scale and the within Ss variable indicated by individual lines. For clarification of type of variable the figure has been reversed. When the prediction distance was long, in the results presented here, it did not matter how long the S viewed the object; when the occluded period was 160 msec performance was better with 80 msec or more of viewing time; when there was no occlusion, performance increased as viewing time increased. However the optimum occlusion distance seemed to be 80 msec, leading to the conclusion that the 0 occlusion served to force the S into a mode of behavior which was abnormal in relation to what would occur if the entire object flight was available. Knowing the ball would be occluded may have caused the player to watch the ball longer than would be normal or necessary. In a "real" situation it is likely that the S would monitor long enough to select a preliminary response and that continued monitoring would be for the purpose of refining the selected response and verification of the choice. However, knowing the occlusion would occur may have caused the S to be more reticent about "sharing" his attention between object monitoring and movement organization, and at the 0 occluded condition he tended to get "caught" without an adequate plan more often than in the 80 msec occlusion. Viewing time may therefore represent processing time and the occluded period movement organization time.

It would seem wiser to use a continuously visible display in which the object speed could be manipulated at various points in order to find out when changes in object speed, or acceleration-decleration characteristics, will fail to evoke a concommitant change in the Ss movement organization. Such an apparatus has been designed and may presently be availble but is very costly since it utilizes computer operated displays.

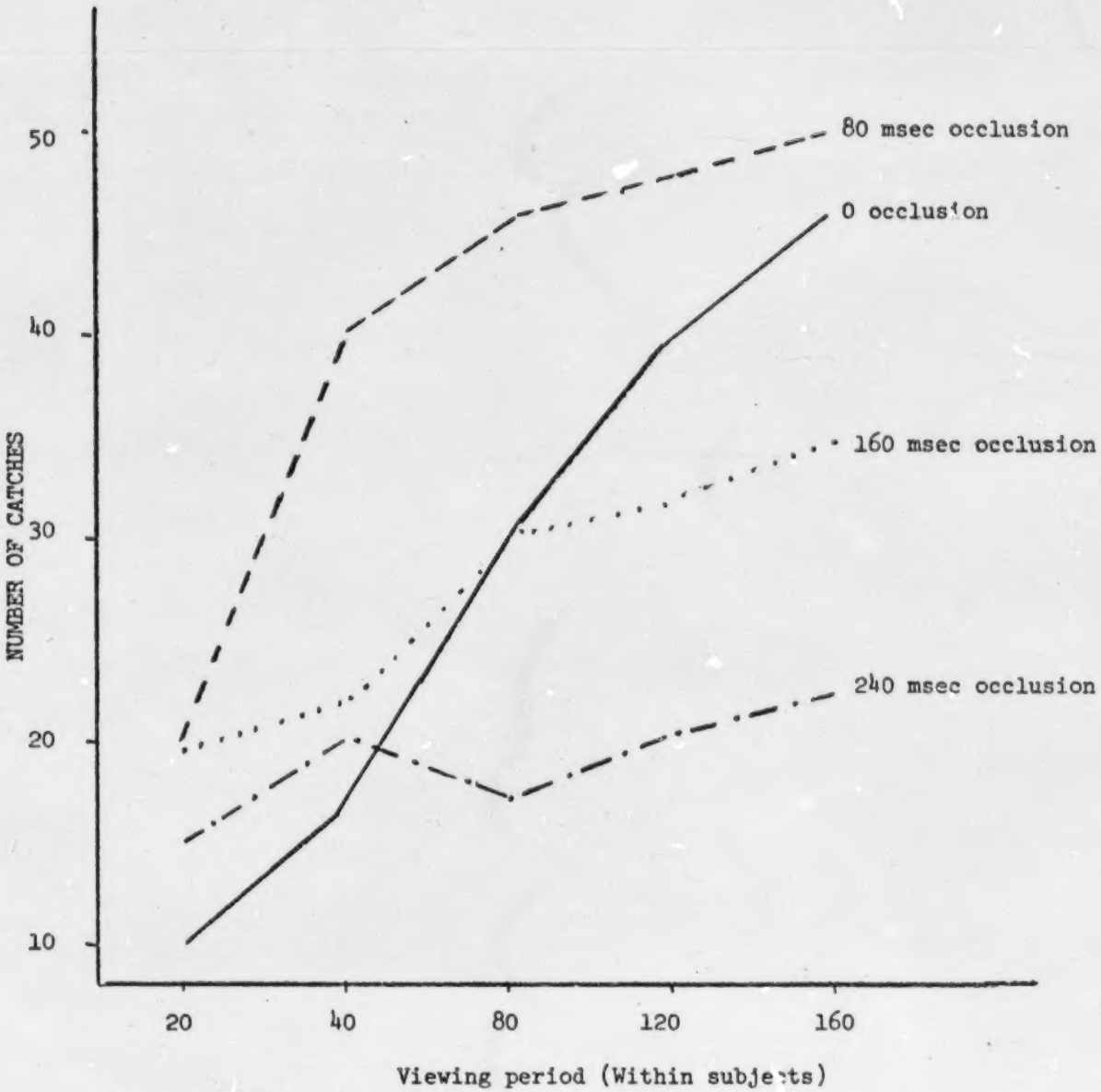


Figure 13: Number of successful catches for viewing period and occlusion condition

Sharp and Whiting, 1974

A more applied study was conducted by Snyder (1966) in which a pair of outfielder's glasses was used to vary the visual occlusion of a tennis ball. It seemed that on the forehand drive the player was still successful if the view of the ball was occluded at the farthest distance, 9'. For the backhand, even in the case of the experienced players used in the study, the longer the players could see the ball when it was traveling at the fast speed, the more accurately the player could hit it. Note that backhand objects come to the non-dominant side of the body and so these results seem to be similar to some of the others, even though the techniques are slightly different. The question here is whether the difficulty observed is related to the angle of the object, the difficulty of the motor organization, or the the difficulty of the integration. It is possible that objects to the forehand side are more readily "encoded" and "predicted" through use of cue abbreviation, so that the information closer than 9' was redundant. Balls to the backhand at faster speeds needed to be attended to for the longest period of time possible because the adjustments and movements tend to be less sutomatic. Although the experience of the players varied from 7-22 years the data was not reported in this manner and so some of the possible hypotheses would be difficult to assess with the available data.

Object flight characteristics. It appears that objects traveling at a constant rate of speed are more easily predicted than are objects which accelerate and these in turn are simpler than objects which are declerating.

SUMMARY

It must again be reiterated that there are many problems associated with the interpretation of the object characteristics because of the interactive nature of the variables and the difficulties inherent in some of the research

designs which have been employed particularly with regard to what is known about information processing. Even so, the information has been organized according to an information processing model with particular attention to the characteristics of the S, the characteristics of the environment and the characteristics of the object and the effect of these upon coincidence-anticipation ability and performance. It is hoped that this consideration and the application of some of the ideas by the teacher of skills may help to facilitate learning and performance in open skills.

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FOOTNOTES

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